APPARATUS WITH AIR-CONDITIONING SYSTEM, AND DEVICE MANUFACTURING METHOD USING THE SAME

FIELD OF THE INVENTION AND RELATED ART

Sub A1 This invention relates to an apparatus having an air-conditioning chamber wherein a high temperature stability is required and, more particularly, to an apparatus having an air-conditioning system to be connected to a high precision optical measurement system or to an environment chamber surrounding the same, such as, for example, a semiconductor manufacturing apparatus or an inspection or measuring apparatus.

The linewidth of a semiconductor integrated circuit has been narrowed more and more. Currently, a pattern of a linewidth of 0.1 micron order can be formed through mass production. As regards the registration precision to be accomplished in an exposure apparatus to meet this, a very strict level of 40 - 25 nm is required. Also, a much more strict level is required for the dimensional precision of a reticle. On the other hand, from the standpoint of enhancement of productivity, the wafer size is changing, from prevalently used 8-inch wafers to 12-inch wafers.

As regards the reticle-to-wafer registration precision in exposure apparatuses, for example, the

measurement precision for the position of a wafer (or of a wafer stage carrying it) is one of critical error factors. This is also with the case of a registration inspecting apparatus. Generally, in such apparatuses, the precise measurement is made by use of a laser interferometer measuring system wherein a change in refractive index in an ambience of a laser light path or a change in temperature thereof has an adverse influence on the measurement error. In addition to these apparatuses, a laser interferometer measuring system is used in a reticle coordinate measuring system for measuring a pattern on a reticle, or a surface shape measuring system for measuring the surface shape of an object, particularly, an optical element.

On the other hand, in exposure apparatuses, a temperature change in a gas, including a projection optical system from a reticle to a wafer, or a temperature change in the projection optical system itself, will adversely affect the image quality of a reticle pattern to be transferred to the wafer.

In an apparatus for precise measurement or an apparatus having a high-resolution projection optical system, for example, the whole of and/or a portion of the apparatus may be surrounded by an environment chamber, and an air-conditioning system may be connected thereto. Alternatively, without use of such

environment chamber, an air-conditioning system may be directly connected to the apparatus so that only a desired portion is placed in a temperature-stabilized gas flow.

Here, as an example, description will be made on semiconductor exposure apparatuses.

In currently available semiconductor exposure apparatuses which meet production of 64M- to 256 M-DRAM, the smallest linewidth of a pattern to be transferred to a wafer is about 0.2 - 0.3 micron. Usually, the required registration precision is about 1/5 to 1/4 of the smallest linewidth and, in this example, it is about 40 - 50 nm. The measurement precision required for a laser interferometer measuring system to accomplish the above-described registration precision, is 1/5 or less of the registration precision and, in this example, it is about 10 nm or less. On the other hand, where an interferometric measuring system having a He-Ne laser as a light source is placed in an atmosphere, there may occur a measurement error attributable to a change in refractive index of the air. It may be about -1 ppm with respect to an air temperature change of 1 ^{o}C. The wafer stage measurement distance required for an exposure apparatus to meet 8-inch wafers is more than 300 mm. Therefore, the air temperature stability around the measurement light path should be less than

0.03 ^{o}C.

Further, in near future, a pattern of 0.1 micron linewidth will have to be formed by mass production, and a much strict level of 40 - 25 nm will be required for the registration precision in an exposure apparatus. Also, 12-inch wafers will be used prevalently for an enhanced productivity, and in such case the largest measurement distance will be more than 400 mm. In consideration of enhancement of the required registration precision or enlargement of the measurement distance such as described above, for example, it is desirable to improve the temperature stability around the measurement light path much more, to a level of 0.01 ^{o}C, for example.

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an improved arrangement by which a change in temperature of an air-conditioning air can be reduced significantly.

It is another object of the present invention to provide an improved arrangement by which an adverse influence of vibration of a refrigerator or the like upon an equipment accommodated in a chamber is removed or reduced.

In accordance with an aspect of the present invention, there is provided an apparatus, comprising:

Sub A3 a chamber having an inner space; and an air conditioner for controlling an air supplied or to be supplied into the inner space of said chamber, said air conditioner including (i) a refrigerator using a refrigerant, (ii) a first heat exchanger for exchanging a heat between the refrigerant and a coolant, and (iii) a second heat exchanger for exchanging a heat between an air supplied or to be supplied into said chamber and the coolant; wherein the refrigerant is circulated between said refrigerator and said first heat exchanger, and wherein said coolant is circulated between said first and second heat exchangers.

Sub A4 A water, an anti-freeze, or a fluoride inert liquid, more specifically, a liquid having a large heat capacity such as a pure water, an ethylene glycol aqueous solution, or a PFC liquid, for example, may be used as a secondary refrigerant. In order to prevent an adverse influence of vibration of a refrigerator or the like upon an equipment inside a chamber, a refrigerator, a secondary refrigerant cooling heat exchanger, and a secondary refrigerant circulating means may be disposed in a casing, separate from the chamber, while an air heating means and a air cooling heat exchanger may be disposed adjacent the chamber.

In a preferred embodiment of the present invention, a manufacturing apparatus such as a

semiconductor manufacturing apparatus or an inspecting or measuring apparatus may be disposed in a chamber.

Sub E1 A refrigerant to be used with a refrigerator may function to cool a coolant, in a first heat exchanger (evaporator), and the cooled coolant may be introduced into a second heat exchanger, to cool an air-conditioning air. The coolant may comprise a liquid such as a pure water, an ethylene glycol aqueous solution, or a PFC liquid, for example, which may have a large heat capacity as compared with a refrigerant (e.g., Flon, substitute Flon, propane, etc.) to be used with the refrigerator. Also, because it is a liquid, any pressure change does not directly cause a temperature change. For these reasons, any temperature change in the refrigerant may be sufficiently smoothed by the coolant having a large heat capacity.

Thus, a coolant being stable with small temperature change may be introduced into an air cooling heat exchanger by means of a circulation pump to cool an air-conditioning air. This enables supply of a conditioning air having a very high temperature stability of 0.01 ^{o}C or less, substantially free from a temperature change in a refrigerant.

Since a liquid to be used as the coolant may large heat capacity, the temperature .bution of the air-cooling heat exchanger itself

can be suppressed to small. As a result, the uniformness of temperature distribution of the conditioning air to be cooled there can be improved more.

A refrigerator or the like which may be a vibration source may be isolated from a secondary refrigerant cooling heat exchanger or a secondary refrigerant circulating means, and it may be disposed separately from a chamber. This is effective to much reduce the vibration to be transmitted to the chamber.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of an environment chamber and an air-conditioning system, according to a first embodiment of the present invention.

Figure 2 is a schematic view of an environment chamber and an air-conditioning system, according to a second embodiment of the present invention.

Figure 3 is a schematic view of an environment chamber and an air-conditioning system, to be compared with the present invention.

Figure 4 is a flow chart of semiconductor device manufacturing processes.

Figure 5 is a flow chart for explaining details of a wafer process in the procedure of Figure 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 3 shows a comparative example for better understanding of the present invention, and it illustrates an example of an air-conditioning chamber for use in a semiconductor exposure apparatus or an inspecting apparatus, for example, as well as an air-conditioning system connected to the chamber.

In Figure 3, disposed inside an air-conditioning system 2 are a cooling heat exchanger (evaporator) 3 for cooling an air, a heating heat exchanger 4 for raising and adjusting the temperature of the cooled air to a predetermined temperature, and an air blower 5 for supplying an air from the air-conditioning system 2 into an environment chamber 1. Here, the term "air" means an ordinary air or a pure gas such as an inert gas, for example. Also, there is a cooling system comprising a refrigerator 6, and a refrigerant is circulated between the cooling heat

exchanger (evaporator) 3 and the refrigerator 6. The cooling heat exchanger (evaporator) 3 comprises a plate fin coil type heat exchanger which includes a plurality of plate fins disposed equidistantly and a plurality of tubes, providing refrigerant flow passages and extending through the fins orthogonally thereto.

The refrigerator 6 includes at least a compressor 7 and a condenser 8. There are various cooling flow rate regulating valves (flow control valves) or other regulating valves (not shown) which are provided, as required, to regulate the pressure or temperature of the refrigerant. Further, there is an accumulator (not shown) which is provided, as required, after the compressor 7 or the condenser 8 for stabilization of the refrigerant pressure. As the refrigerant b, HCHC such as R22, R134a or R407c, for example, HFC gas, ammonia or methane gas, for example, is used. The refrigerant gas b as pressurized and heated by the compressor 7 of the refrigerator 6 is subject to heat exchange, at the condenser 8 and with a cooling water c, whereby it is cooled and liquefied. Further, this refrigerant liquid passes through an expansion valve or capillary 30, and it is flown to the cooling heat exchanger (evaporator) 3, as a refrigerant b' having its temperature lowered by evaporation and adiabatic expansion. Then, after

depriving the heat of the conditioning air at the cooling heat exchanger (evaporator) 3, the refrigerant is pressurized again by the compressor 7. Through a refrigerating cycle wherein expansion, compression and heat wasting of a refrigerant are made continuously in a closed circuit, the conditioning air is cooled by wasting its heat into the cooling water.

In the environment chamber 1, an air a is cooled by the cooling heat exchanger (evaporator) 3 and then it is held at a predetermined temperature by the heating heat exchanger 4. The heating heat exchanger 4 is provided with an electric heater 4'. A temperature sensor 9 and this electric heater 4' which are disposed inside the environment chamber 1 or the air-conditioning system 2, are electrically communicated with each other through a temperature adjusting device 10 and an output converter (not shown). The temperature adjusting device 10 controls the output of the electric heater 4' through the output converter, in accordance with a control algorithm such as PID control, for example, such that the temperature as detected by the temperature sensor 9 is kept at a predetermined level. The air a' maintained at a predetermined temperature by the heating heat exchanger 4 is then sucked up by the air blower 5 and is flown to the environment chamber 1.

The environment chamber 1 is provided with a

filter box 12 having a dust removing filter 11 such as HEPA or ULPA filter accommodated therein. The air a" having its dust or particles removed by the filter 11 is supplied to a space 14 in which an exposure apparatus 13 is placed. The air a" supplied to the space 14 is discharged through a returning port 15 provided in the air-conditioning system 2, such that it is circulated between the air-conditioning system 2 and the environment chamber 1. Usually, the space 14 is kept at a pressurized state slightly higher than the atmospheric pressure of the external environment in which the environment chamber 1 is placed. To this end, an air of 5 - 10% of the circulation air quantity is introduced thereinto, from an outside air introducing port 16. Further, in an exposure apparatus, an impurity removing filter may be disposed along the outside air introducing path or the circulation path, so as to remove an organic (gas) or acid or alkali gas in the air to meet a chemical amplification resist or blurring of an optical element.

However, with the cooling of air-conditioning air through a refrigerating cycle wherein expansion, compression and heat wasting of a refrigerant are performed continuously in a closed circuit, there occurs a change in expansion pressure due to a change in compression pressure of the refrigerant b by the

compressor 7 or a change in temperature or flow rate of the cooling water c, flowing through the condenser 8. Such change in refrigerant expansion pressure then causes a temperature variation in the cooling heat exchanger (evaporator) 3, which in turn results in a temperature variation of the air-conditioning air a to be cooled thereby. The temperature response of the cooling heat exchanger (evaporator) 3 to the expansion pressure change is very quick and sensitive. The response speed of the electric heater 4' inside the heating heat exchanger 4 is too slow to cancel the same through control of the heater 4'. As a result, a temperature change of about 0.02 ^{o}C will undesirably remain in the air-conditioning air a'.

Further, vibration of the air-conditioning system 2 is transmitted to the main assembly 13 of the manufacturing apparatus via the environment chamber 1 or the floor on which the chamber is placed. This adversely affects the measurement error, and it causes a large factor for degradation of the registration precision or image performance. This is because the compressor 7 of the refrigerator 6 or the air blower 5, provided in the air-conditioning system, functions as a major vibration source.

Some preferred embodiments of the present invention will be described below.

Figure 1 is a schematic view of an apparatus

having an air-conditioning chamber according to a first embodiment of the present invention. In this embodiment, the invention is applied to a semiconductor manufacturing apparatus such as a stepper, for example.

In this embodiment as illustrated in Figure 1, as compared with the example shown in Figure 3, there is a circulation circuit for a coolant, which is added to an air-conditioning system 2. More specifically, there are additional components such as a coolant cooling heat exchanger (evaporator) 17 which functions as a first heat exchanger for cooling a coolant d with use of a refrigerant b' of a refrigerator 6, an air-conditioning air cooling heat exchanger 3' for cooling the air-conditioning air through heat exchange with the coolant having been cooled by the heat exchanger 17, a reservoir 18 for temporarily reserving the coolant, and a pump 19 for feeding out the coolant reserved in the reservoir 18. In addition to them, there are various safety devices or control and regulating devices, such as a pressure regulating valve for preventing pressurization of the reservoir 18, a flow rate control valve for regulating the circulation flow rate of the coolant, a pressure monitoring device for monitoring the pressure inside the circulation path, all being provided as required.

As regards the heat exchanger (evaporator)

17, a plate type heat exchanger, a heat exchanger having tubes or coils embedded in a shell, or a double tube type heat exchanger may be used. The refrigerant gas b as pressurized and heated by the compressor 7 of the refrigerator 6 is subject to heat exchange, at the condenser 8 and with a cooling water c, whereby it is cooled and liquefied. Further, this refrigerant liquid passes through an expansion valve or capillary 30, and it is flown into the cooling heat exchanger (evaporator) 17, as a refrigerant b' having its temperature lowered by evaporation and adiabatic expansion. Then, after depriving the heat of the coolant d at the heat exchanger (evaporator) 17, it is pressurized again by the compressor 7.

On the other hand, the coolant d fed by the pump 19 and cooled by the heat exchanger (evaporator) 17 is flown to an air-conditioning air cooling heat exchanger 3' (second heat exchanger) to cool the air-conditioning air there. The coolant d having deprived the heat of the air-conditioning air is collected into the reservoir 18, and again it is fed by the pump 19 into the heat exchanger (evaporator) 17. In this manner, the coolant is circulated between the heat exchanger (evaporator) 17 and the heat exchanger 3', by which the heat of the air-conditioning air is transferred to the refrigerator 6.

As regards the coolant, a liquid such as

pure water, anti-freeze liquid, or PFC liquid, for example, may be used. These liquids have a large product of specific heat capacity and specific gravity, and the heat capacity to be transferred per a unit temperature is very large as compared with that of ordinary refrigerant. In the case of ordinary refrigerant, a phase change follows and it can not be compared simply. However, for the same heat capacity, a temperature change resulting from heat radiation and reception is considerably small with these coolants. Also, since they are held as liquid over the whole temperature range used, there is an advantage that a pressure change does not directly apply an influence to a change in temperature. The anti-freeze liquid may comprise a solution of ethylene glycol, for example, mixed into a pure water or tap water, for prevention of freezing. The PFC liquid is a fluorine series inert liquid. Since it has a good electric insulation property, it may be used preferably in a case where a risk of short-circuit due to leakage of the liquid should be avoided. Recently, in relation to the fluorine series inert liquid, HFE (hydrofluoro ether) and HFPE (hydrofluoro polyether), having a small earth warming coefficient and being good for the environment, have been developed. They may of course be used.

Figure 2 is a schematic view of an apparatus

with a cooling system, according to a second embodiment of the present invention. An environment chamber has the same structure as of the first embodiment, and it is not illustrated. The second embodiment has a similar structure as of the first embodiment except for the following points.

An air-conditioning air cooling heat exchanger 3' and a coolant tube are left in an air-conditioning system 2, while on the other hand, various components including a refrigerator 6 for cooling the coolant as well as a pump 19 and a reservoir 18 are structured into a cooling system 20 which is made separate from the air-conditioning system 2. The cooling system 20 and the air-conditioning system 2 are connected with each other through pipes for circulating the coolant between them. The length of this piping may be made more than 20 m, such that the cooling system 20 and the air-conditioning system 2 can be mounted at completely different places, such as, for example, a place below a clean room or a separate room. The connection pipes may be surrounded by a heat insulative material if necessary, by which transfer of heat from the outside environment into the coolant can be prevented efficiently.

As described hereinbefore, a refrigerant of a refrigerator is used to cool a coolant, and the

coolant is circulated as a cooling medium for a second heat exchanger. As a result of it, a coolant having a large heat capacity as compared with that of the refrigerant for the refrigerator can be used and introduced into the second heat exchanger, to perform cooling of the air-conditioning air. The temperature change of or any temperature non-uniformness in the air to be cooled and conditioned can therefore be reduced significantly. By heating again the air having small temperature change or small non-uniformness of temperature to control its temperature to a predetermined level, as a consequence of it, the temperature change in the air-conditioning air to be supplied into the chamber can be reduced to 0.01 ^{O}C or less. Further, since the refrigerator or the like can be placed separate from the second heat exchanger, the refrigerator or the like which may function as a vibration source can be disposed away from the chamber. This effectively reduces transmission of vibration to the chamber. Therefore, where a measuring apparatus having a laser interferometric measuring system, particularly, a semiconductor exposure apparatus such as a stepper, a registration inspecting apparatus, a reticle inspecting apparatus or a surface shape measuring apparatus, for example, are disposed in a chamber, a measurement error due to a temperature change or vibration can be reduced

significantly.

Figure 4 is a flow chart of procedure for manufacturing microdevices such as semiconductor chips (e.g. ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example.

Step 1 is a design process for designing a circuit of a semiconductor device. Step 2 is a process for making a mask on the basis of the circuit pattern design. Step 3 is a process for preparing a wafer by using a material such as silicon. Step 4 is a wafer process (called a pre-process) wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step (called a post-process) wherein the wafer having been processed by step 4 is formed into semiconductor chips. This step includes an assembling (dicing and bonding) process and a packaging (chip sealing) process. Step 6 is an inspection step wherein operation check, durability check and so on for the semiconductor devices provided by step 5, are carried out. With these processes, semiconductor devices are completed and they are shipped (step 7).

Figure 5 is a flow chart showing details of the wafer process.

Step 11 is an oxidation process for oxidizing the surface of a wafer. Step 12 is a CVD process for

forming an insulating film on the wafer surface. Step 13 is an electrode forming process for forming electrodes upon the wafer by vapor deposition. Step 14 is an ion implanting process for implanting ions to the wafer. Step 15 is a resist process for applying a resist (photosensitive material) to the wafer. Step 16 is an exposure process for printing, by exposure, the circuit pattern of the mask on the wafer through the exposure apparatus described above. Step 17 is a developing process for developing the exposed wafer. Step 18 is an etching process for removing portions other than the developed resist image. Step 19 is a resist separation process for separating the resist material remaining on the wafer after being subjected to the etching process. By repeating these processes, circuit patterns are superposedly formed on the wafer.

With these processes, high density microdevices can be manufactured.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.